# SPEED CONTROL TO PREVENT RETURN GAS BLOWER SURGING

# COMMANDE DE VITESSE POUR LA PREVENTION CONTRE LE POMPAGE DE LA SOUFFLANTE A GAS DE RETOUR

Yasumasa Kitano
Fujio Masuda
Tatsuo Kiso
Osaka Gas Co., Ltd.
4-1-2, Hirano-machi, Chuo-ku, Osaka, Japan

## ABSTRACT

Osaka Gas Co., Ltd. has built a new LNG unloading berth "Berth No. 2" at its main plant "Senboku LNG Terminal II", which has been in operation since November 1994. The return gas blower system installed at this berth adjusts return gas flow rate by controlling blower (revolving) speed. This method was adopted for flow rate control of return gas blower for the first time in the world.

This control method enables the return gas blower system to use a broader return gas flow rate control range without surging, and enhances controllability. In addition, it substantially decreases blower operation power requirement (80 % reduction from conventional method used by the damper control). Osaka Gas has long been engaged in various environment protection activities, and obtained certification for ISO14001, the international standard on Environmental management system, in October 1997. This saving of return gas blower operation power is part of such activities.

## RESUME

Osaka Gas Co., Ltd. a construit dans son usine principale "Terminal GNL II de Senboku" un nouveau quai de déchargement de GNL "Quai n° 2" qui a été mis en service en novembre 1994. La soufflante à gaz de retour du quai considéré adopte une commande de vitesse (de rotation) de la soufflante qui est le premier système dans le réglage de débit de gaz de retour.

Ce système a élargi la gamme de réglage de débit de gaz de retour, a assuré la prévention contre le pompage et a amélioré la contrôlabilité. De plus, l'énergie électrique requise pour le fonctionnement de la soufflante a été considérablement réduite (taux de réduction intérieur de la société : 80%). Par ailleurs, notre société a obtenu en octobre 1997 une attestation selon la norme internationale du système de gestion de l'environnement "ISO14001". La réduction de l'énergie électrique requise pour le fonctionnement de la soufflante a contribué à ladite activité.



RETURN HOME

## 1. Introduction

Osaka Gas Co., Ltd., one of Japan's leading gas utilities, supplies city gas (natural gas) to some 6 million customers (as of October 1997) in the midwestern area of Japan. Senboku LNG Terminal II, our main plant, produces 50 % of the company's total city gas sales. This plant began receiving LNG from Indonesia in August 1977, from Australia in August 1989, and from Malaysia in July 1995; it now receives a total of some 5.8 million tons/year of LNG (in fiscal 1996).

To accommodate the increasing LNG quantities received, the company built a new unloading berth "Berth No. 2" for this plant; the berth commenced operation in November 1994. Before construction, we conducted design review with reference to the operation status of the company's existing berths, to ensure a safer and easier-to-operate berth.

With the aim of preventing return gas blower surging, this berth adopted the blower (revolving) speed control method, for the first time in the world, to control the return gas flow rate.

This paper (1) describes blower speed control for surging prevention, (2) presents return gas flow rate control status, and (3) reports how blower operation power requirement has been decreased substantially.

## 2. Purpose and Control of Return Gas Blower

### 2.1 LNG Unloading and Return Gas

A return gas blower (RGB) is one of various unloading facilities for receiving liquefied natural gas (LNG) from LNG tankers. As LNG is unloaded from an LNG tanker into a receiving tank, the tanker cargo tank pressure drops gradually. The purpose of the RGB is to return boil-off gas (BOG) from the receiving tank to the cargo tank, thereby maintaining a constant cargo tank pressure. BOG thus returned to the cargo tank is called "return gas". Fig. 1 shows the concept of LNG unloading operation.

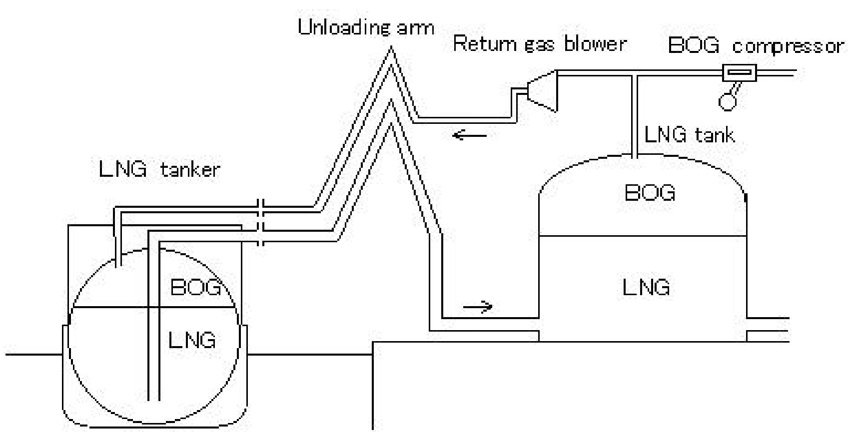



Fig. 1 Concept of LNG Unloading Operation

Normally, BOG is returned under pressure by operating the RGB, to compensate for pressure loss in the return-gas piping. If the return-gas piping is short, with little pressure loss in the piping, BOG may be returned in free flow, using the differential pressure between the receiving tank and the cargo tank.

## 2.2 Return Gas Flow Rate Control

The return gas flow rate required to maintain a constant cargo tank pressure varies depending on the LNG tanker type, the cooling performance of the cargo tank, LNG temperature, season, cargo pump capacity, unloading rate, progress of unloading operation, etc. It is therefore necessary to control the return gas flow rate, which is conventionally controlled via damper (damper control). The following paragraphs describe this control method and the occurrence of surging.

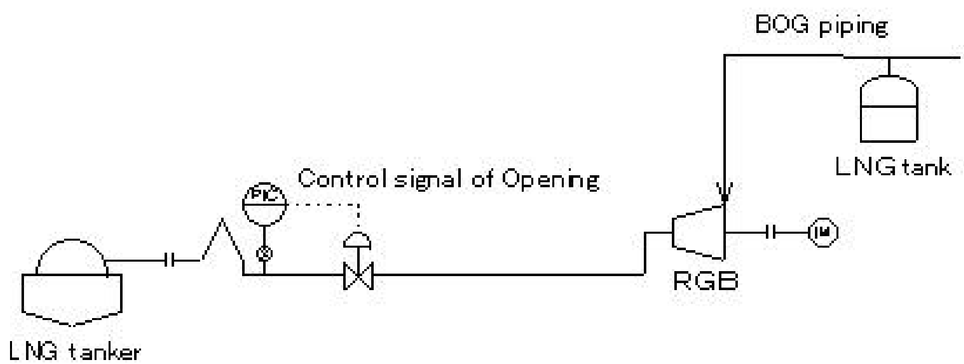



Fig. 2 Control Flow Diagram (Damper Control)

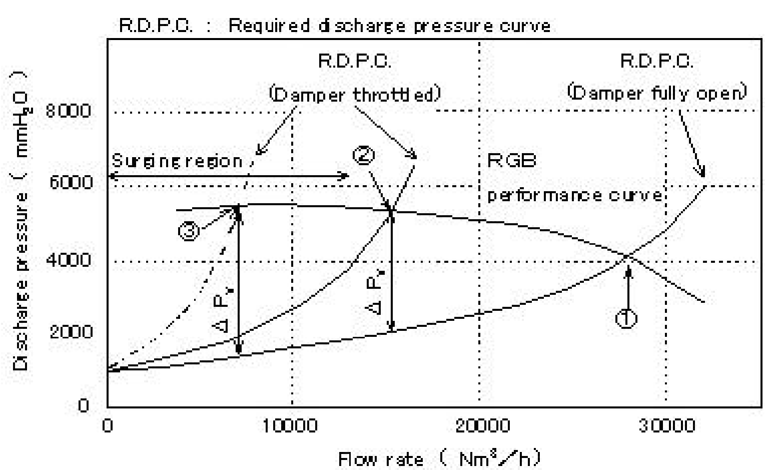



Fig. 3 Control Concept (Damper Control)

Figs. 2 and 3 show the flow and the concept, respectively, of damper control. In Fig. 3, the horizontal axis represents the flow rate, the vertical axis the discharge pressure. RGB performance decreases as the flow rate increases. By contrast, the required RGB discharge pressure, which is the sum of the cargo tank pressure setting and the pressure loss in the return-gas piping from RGB to LNG tanker, increases with the flow rate. The point of intersection between the RGB performance curve and the required discharge pressure curve is the RGB operating point.

Assuming that RGB is operated at point ①, if cargo tank pressure rises above the PIC setting, damper opening is throttled. Damper pressure loss $\Delta P_V$ then increases, resulting in steeper required discharge pressure curve. As a result, RGB is operated at point ②, to decrease the flow rate. If required flow rate is still lower, damper opening is further throttled, so that RGB is operated at point ③, which is in the surging region.

Surging is the phenomenon in which a turbo compressor, such as a return gas blower, vibrates and generates noise as the discharge flow rate and pressure fluctuate periodically in the low flow rate range. Since continued surging would cause mechanical damage to the blower, appropriate measures must be taken to prevent surging.

## 3. Design of RGB for Berth No. 2

### 3.1 Design Challenges

Fig. 4 shows the layout of RGB at Berth No. 2, an overall view of which is shown in attached photo.

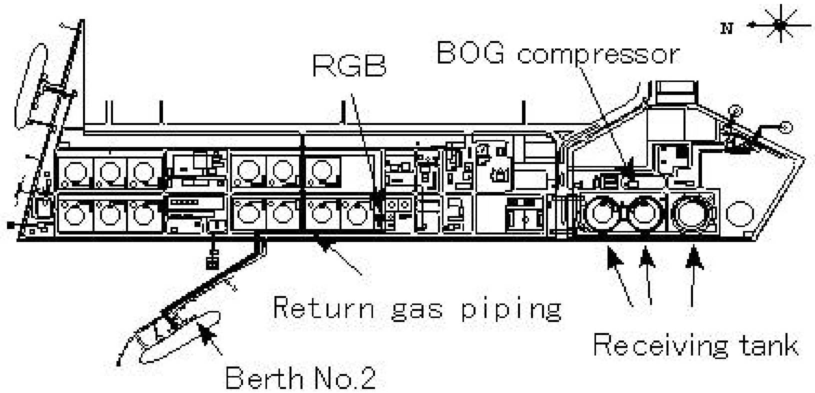



Fig. 4 Layout of RGB (Senboku LNG Terminal II)

RGB for Berth No. 2 posed the following design challenges:

(1) Extremely long return gas piping

As shown in Fig. 4, Berth No. 2 is located in the sea, 450 m off shore. The return gas piping from the berth to the RGB is 800 m in length (400 mm nominal size), more than twice that for Berth No. 1 (400 m, 450 mm nominal size.) at the same plant. Piping pressure loss is therefore quite considerable.

(2) Extremely wide fluctuation in return gas flow rate

Berth No. 2 is designed to accommodate LNG tankers of the 20,000 - 130,000 $m^3$ class. The return gas flow rate therefore fluctuates over an extremely wide range, from 5,000 - 27,000 $Nm^3/h$.

(3) RGB operation status at existing berths

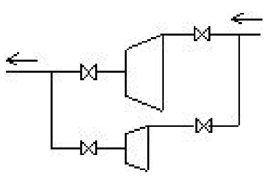
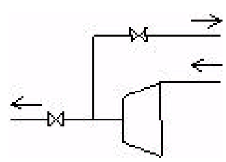
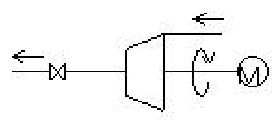
At existing berths, RGB suffers surging several times a year. It is difficult to control return gas flow rate each time surging occurs.

The design flow rate of Berth No. 2 RGB is 27,000 $Nm^3/h$, and surging occurs at a flow rate of around 13,000 $Nm^3/h$. For problem-free RGB operation surging preventive measures are indispensable at the minimum flow rate of 5,000 $Nm^3/h$.

## 3.2 Prevention of Surging

To prevent surging, various methods were studied. Table 1 compares some typical methods.

Table 1 Comparison of Surging-preventive Methods

| Method | [Method 1] Installation of Large- and Small-capacity RGBs | [Method 2] Bypass Piping | [Method 3] RGB Speed Control |
|---|---|---|---|
| Principle | Large- and small-capacity RGBs are installed for selective operation according to progress of unloading work, as well as to LNG tanker capacity.  | Part of discharge flow is sent to BOG compressor to keep flow rate above surging point.  | RGB revolving speed is controlled to change blower characteristics, thereby lowering flow rate at which surging occurs.  |
| Charac-teristics | Multiple RGBs are needed, resulting in high construction cost.<br>Large installation space requirement<br>Complex channel-switching operation | Additional piping is needed between RGB and existing BOG pre-cooler, resulting in high construction cost.<br>Large operation power requirement | Low construction cost<br>Easy flow rate control<br>Few operation power requirement |
| Adopt-ability | Not adopted | Not adopted | Adopted |

Method 1 involves the installation of two or more RGBs of different capacities, for selection according to the required flow rate. This method, which involves many RGBs, incurs high construction cost and requires large installation space. In addition, complex operation is needed to switch RGBs.

Method 2 involves keeping flow rate above the surging point by sending part of the RGB discharge gas to the BOG compressor through bypass piping. Required flow rate can also be maintained by returning part of the discharge flow from the RGB directly to the intake side of the RGB. In that case, however, intake temperature rises, although return gas temperature must be extremely low (-140 to –150ºC). RGB therefore cannot be operated continuously for a long time. For method 2, discharge flow is led to an existing BOG pre-cooler and processed in a BOG compressor. Application of this method to Berth No. 2 would necessitate building new bypass piping (900 m long, 300 mm nominal size), which would incur high cost.

Method 3 involves controlling the flow rate via RGB (revolving) speed. This method, called speed control, is based on the fact that flow rate pressure characteristics of RGB are proportional to the revolving speed. The surging region shifts toward the lower flow rate side as RGB speed decreases. By decreasing RGB speed, therefore, it is possible to maintain stable operation without surging, even if the flow rate is low. There are two methods for such speed control: the electrical method, in which the motor is controlled via an inverter; and the mechanical method, which uses fluid coupling. For speed control by either method, construction cost is lower than for method 1 or 2. For the mechanical method, large installation space is required at the site, since the RGB must be quite large, and an hydraulic system is necessary. By contrast, the electrical method, which uses an inverter, does not require a large installation space at the site, since the inverter is installed in a switch house. In consideration of these aspects, we have adopted the electrical speed control method, which involves motor control via inverter.

### 3.3 Motor Control via Inverter

An AC motor runs at around synchronous speed (N), which is determined by power frequency (f) and number of poles (P) as follows: $N = 120f/P$ (rpm)

Therefore, if variable frequency power supply (called “inverter”) is used, the motor speed can be controlled as desired by varying the power frequency. This is inverter control of motor.

## 4. RGB Speed Control

### 4.1 RGB Speed Control

RGB speed control is based on the fact that RGB flow rate-pressure characteristics change with revolving speed. Revolving speed (N), flow rate (Q), pressure (H) and shaft power (P) have the following interrelations:

(1) Flow rate is proportional to revolving speed. ($Q \propto N$)

(2) Flow rate is proportional to the square root of pressure. ($Q \propto H^{0.5}$)

(3) Shaft power is proportional to the cube of revolving speed. ($P \propto N^3$)

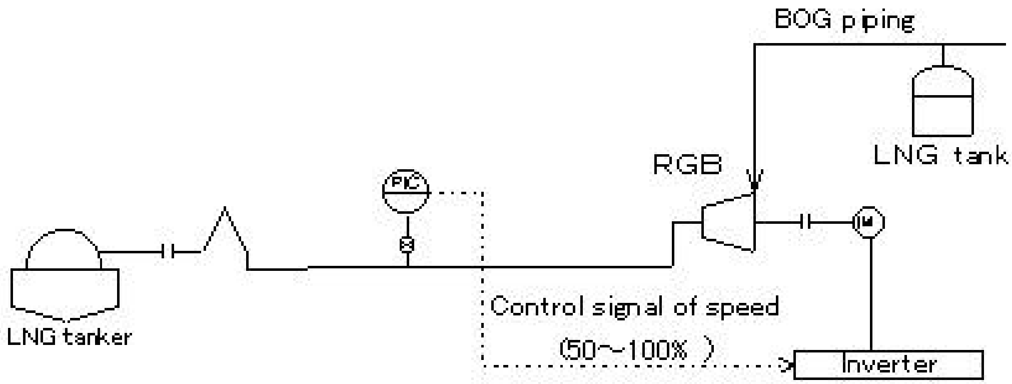



Fig. 5  Control Flow (Speed Control)

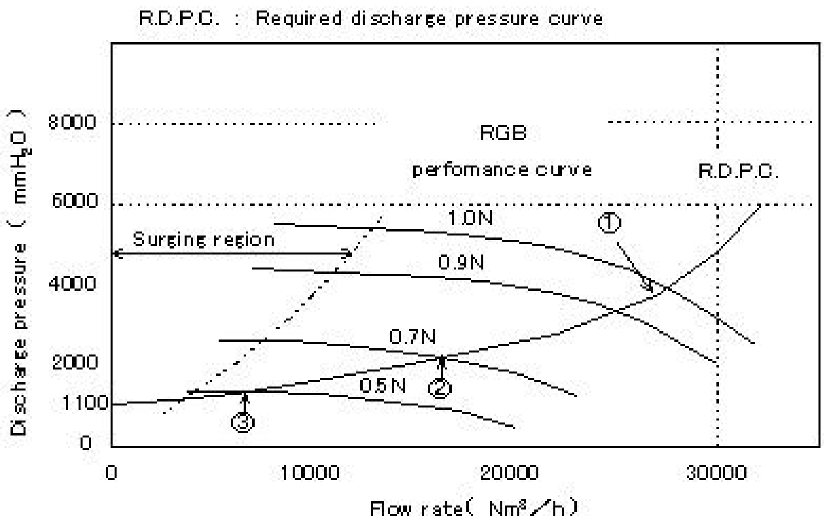



Fig. 6  Control Concept (Speed Control)

Figs. 5 and 6 show the control flow and the control concept, respectively. The power frequency is varied by the inverter to control the RGB speed so that the pressure becomes equal to the PIC setting.  In Fig. 6, typical RGB performance curves are shown for four different speeds between N and 0.5N (N = rated speed).  When required flow rate is high, RGB speed is increased to shift the intersection between required discharge pressure curve and each performance curve, to yield the required flow rate.  When the required flow rate is low, RGB speed is decreased.  RGB speed can be varied continuously between 50 and 100%, depending on the difference between cargo tank pressure and PIC setting.

For example, assuming that RGB is operated at point ①, if cargo tank pressure rises, the RGB speed is decreased relative to the difference between cargo tank pressure and PIC setting, to operate RGB at point ②, the point of intersection between required discharge pressure curve and performance curve for 0.7N.  If cargo tank pressure rises further, RGB speed is decreased so that RGB operates at point ③.

With speed control via inverter, since the flow rate at which surging occurs drops to 5,000 $Nm^3/h$, as compared to 13,000 $Nm^3/h$ with damper control, RGB surging can be prevented.

### 4.2 Effectiveness of Speed Control

(1) Stable Pressure

The speed control method can adjust return gas flow rate more appropriately than the damper control method. Figs. 7 and 8 show operation data concerning cargo tank pressure and return gas flow rate at Berth No. 1 (damper control) and Berth No. 2 (speed control), respectively. With the damper control method, cargo tank pressure fluctuates for some time after start of RGB, until the middle of unloading operation. With the speed control method, in contrast, cargo tank pressure is maintained at almost a constant value.

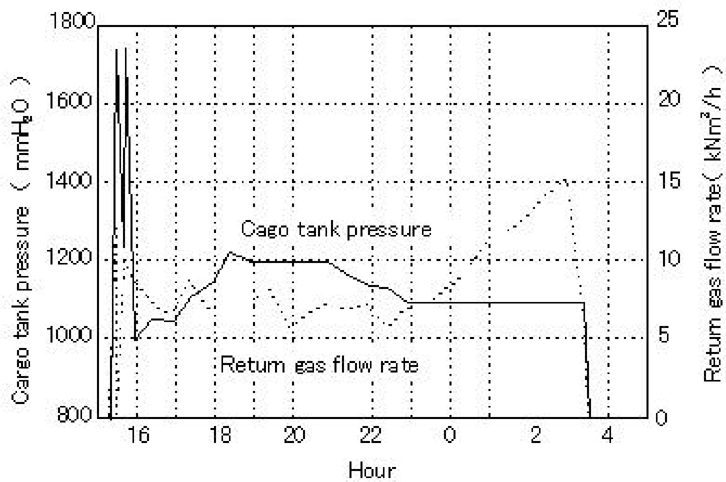



Fig. 7 Operation Data at Berth No. 1 (Damper Control)

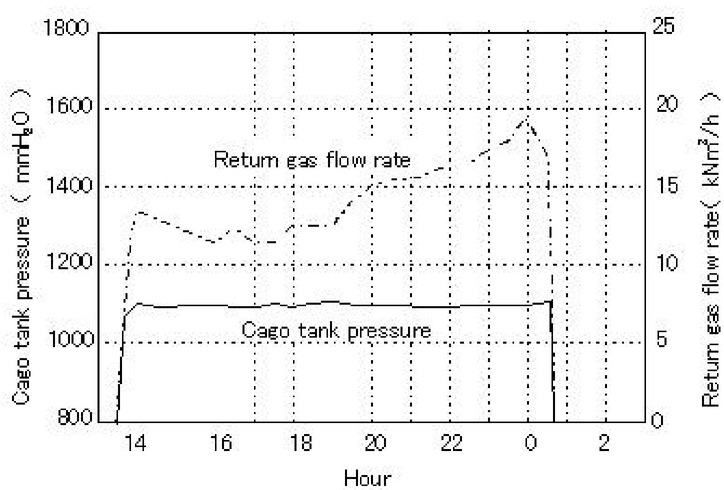



Fig. 8 Operation Data at Berth No. 2 (Speed Control)

(2) 80% Reduction of RGB Operation Power Requirement

Another merit of speed control is its power-saving effect. At Berth No. 2, RGB speed is kept to an average 60% of the rated speed. Since shaft power is proportional to the cube of RGB speed, the RGB operation power requirement at Berth No. 2 is 550 kWh, or 2,000 kWh lower (80% reduction) than the 2,550 kWh at Berth No. 1, with damper control. Fig. 9 shows the relation between return gas flow rate and operation power requirement for each control method. The difference between $P_D$ and $P_N$, ($P_D$ - $P_N$), corresponds to the operation power requirement reduction achieved by speed control.

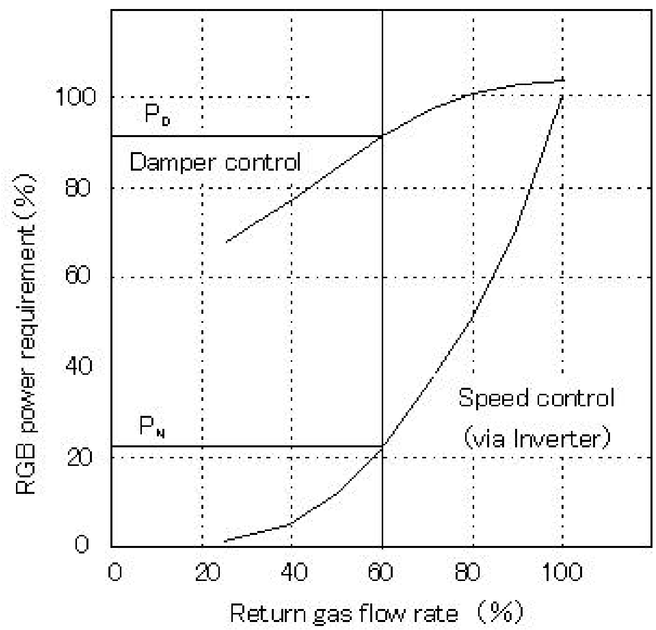



Fig. 9 Operation Power Requirement (Speed Control and Damper Control)

## 5. Conclusions

Various methods for preventing RGB surging have been studied for comparison. Based on the result, the speed control method has been adopted for Berth No. 2 RGB. This control method has the following effects:

(1) Flow rate controllable range has been broadened, so that surging is prevented.

(2) Stable control has been obtained.

(3) Operation power requirement has been reduced substantially (80% lower than that with conventional control method used by damper control).

Osaka Gas has long been engaged in various environment protection activities, and obtained certification for ISO14001, the international standard on Environmental management system, in October 1997. The above-mentioned saving of blower operation power is part of such activities.

The speed control method is also effective in saving construction expenses, if adopted when:

(1) It is necessary to install long bypass piping to prevent RGB surging.

(2) It is necessary to install multiple RGBs of different capacities to provide for various LNG projects.

Overall View of Berth No. 2

LNG Unloading at Berth No. 2